April 1, 1964

Third Quarterly Report On An Investigation of Fluid Extrusion of Metals

January 1, 1964 - April 1, 1964

Contract NASw-742

to

National Aeronautics and Space Administration
Washington, D.C.

by

Pressure Technology Corporation of America
453 Amboy Avenue
Woodbridge, New Jersey

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Gentlemen:

Please find enclosed one copy of the Third Quarterly Report entitled "An Investigation of Fluid Extrusion of Metals", produced under Contract No. NASw-742, for the National Aeronautics and Space Administration.

Yours very truly,

Alfred Bobrowsky /dm

Alfred Bobrowsky
President

AB:dm

Enclosure

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ABSTRACT

Tensile tests and fluid-to-fluid extrusions were made of a chromium dispersion-hardened with magnesium oxide. Orthotropism was found in the powder-metallurgy product. Tensile tests were conducted on tungsten tantalum alloy. This arc-cast material exhibited inhomogeneity due to the large grain size. Hafnium carbide continues to behave in the brittle manner in tensile tests under pressure.

Author

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INTRODUCTION

The previous progress report has provided information on fluid-to-fluid extrusions and on tensile tests of several materials under pressure. The tensile tests served to indicate the feasibility of metal processing in general under pressure. The materials being considered range through large grain metals and powder-metallurgy products. This report covers investigations conducted during the quarterly period January 1, 1964 through April 1, 1964.

This work was conducted under NASA Contract NASw-742.

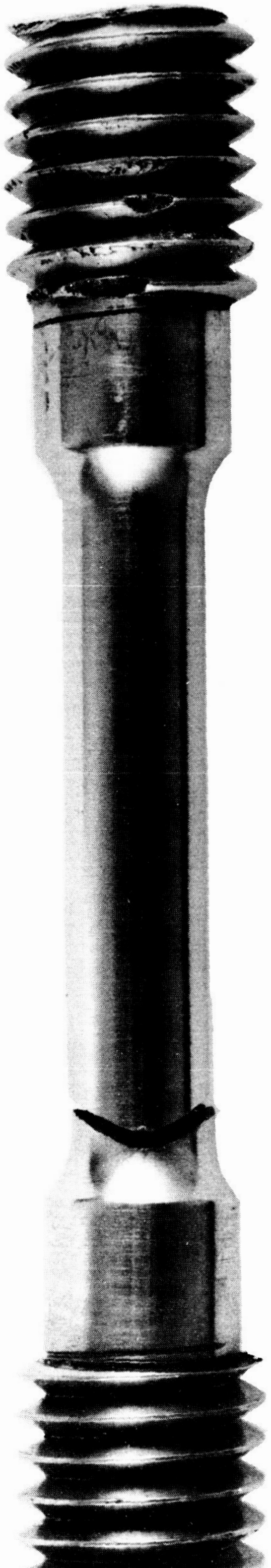
EXPERIMENTAL

Chrome-30 (Chromium-MgO Composite)

One of the specimen materials in this investigation is chromium metal that has been dispersion hardened by MgO, termed Chrome-30 as a trade name. The previous progress report reported attempts to employ high fluid pressures to obtain ductility subsequent to the pressurizations, parallel to work reported from Australia (ref. 1). Figure 1 shows a photograph of the tensile specimen employed for these studies. The specimen is 3" long with a gage section 1" long and .250" diameter. The figure, typical of all specimens, pressurized or unpressurized, shows a brittle fracture originating at the point of contact of the extensometer with the specimen. There was present an increase in 0.2% yield strength due to the use of a jacket on the specimen as previously reported.

Tensile tests under pressure of the material were performed. It was previously reported in the Second Quarterly Progress Report that a tensile specimen of 1/2" nominal gage length was machined. This specimen showed a yield stress of 29,000 psi, UTS of 67,500 psi, with fracture occurring under an environmental fluid pressure of 167,000 psi. This specimen showed 29.5% elongation and 50% reduction in area

Figure 1: Tensile test specimen subjected to high fluid pressures (150,000 psi and 450,000 psi) in order to determine whether ductility could be so obtained. The figure shows a brittle fracture obtained in tensile tests subsequent to pressurization at a strain rate of .01 per minute.



compared to nominal mechanical properties given by the manufacturer as 0.2% yield strength, 30,000 psi to 30,200 psi, UTS 46,000 psi to 48,000 psi, per-cent elongation 20 to 25%, and per-cent reduction in area 13 to 16%. It is thus apparent that the presence of a pressure environment produced a large increase in reduction in area as well as about 30% increase in UTS.

These tests were continued at higher pressures. A two-stage test was conducted as follows: A tensile specimen was pulled under pressure of about 300,000 psi but the test was not carried to completion. Yield stress was determined as 47,000 psi at these pressures, approximately an increase of 50% above that at atmospheric pressure. At the stopping point in the test, the specimen manifested 20% elongation and 35% reduction in area. It was noted that the neck was orthotropic, exhibited manimum and maximum linear dimensions at right angles, normal to the specimen axis. Testing was resumed at slightly higher pressure. This specimen exhibited a yield strength of 70,000 psi after the cold working it had received in the first pulling, although this value again was obtained under pressure. A UTS of 100,000 psi was obtained with fracture at 382,500 psi. The terminal maximums on the material showed 42% elongation and 95.3% reduction in area.

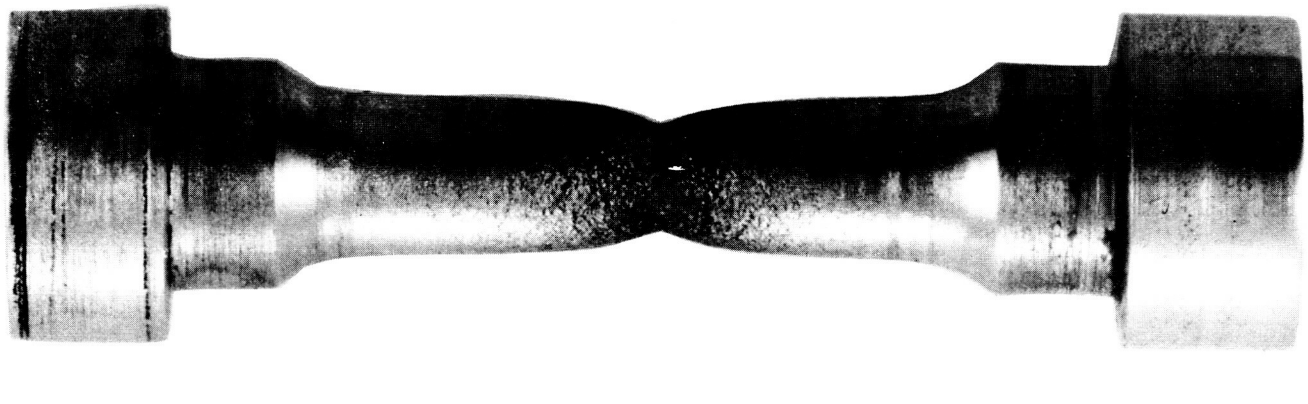
These data indicate that the Chrome-30 material can be cold worked under pressure to achieve a greatly increased yield strength.

The orthotropic behavior of this specimen was sufficiently interesting that another specimen was tested at moderately high pressure. This specimen was fractured at 339,000 psi environmental fluid pressure, manifested a yield strength of 55,000 psi and a UTS of 80,000 psi. The test was stopped short of fracture with the specimen manifesting 37% elongation and 87% reduction in area. The specimen is shown in figure 2. It can be seen that the necking is definitely orthotropic.

There are several points of interest in the results that have been presented. One is that this material can be cold worked to achieve significant increase in physical properties. Although the physical properties after straining under pressure were not measured at atmospheric pressure, it is evident that the yield strength at atmospheric pressure can be increased by suitable working under pressure.

One interpretation of the orthotropic behavior of the Chrome-30 specimens is based upon a supposed process procedure. If it is postulated that this material was processed by pressing powder, the type of pressing is of interest. It is believed that isostatic (hydrostatic)

Figure 2: Chromium dispersion-hardened with MgO, tensile test specimen stopped short of fracture manifesting 37% elongation and 87% reduction in area at stage shown. Orthotropic necking is evident.



pressing would produce uniform and isotropic physical properties in this material. If, however, the material is pressed in a closed mold, the stresses parallel to the direction of pressing will be greater than those at right angles. This would be especially true if there were not adequate lubricant between the powder particles during the pressing operation. Thus, if the specimen were pressed parallel to the rod axis, one might expect a greater packing of the powder particles parallel to the rod axis and a lesser packing transversely. If, however, the rod were pressed normal to the rod axis (direction "N"), one would expect a greater density of packing of particles in the "N" direction or in the direction normal to both (termed binormal or "B" direction).

It is believed that this concept of differences in density of packing in different directions is original with this progress report. One would consequently expect a different Poisson's Ratio as well as different lateral contractions in plastic flow during the tensile test.

Another explanation of the orthotropic behavior can be that the powder particles were lamellar or acicular, and that this produced a texture on packing during pressing.

This is not a probable explanation since it would assume that particles at great distances from each other suffered no relative misorientation during the pressing process.

Interestingly enough, if the pressing process does indeed produce differences in packing as indicated, this fact may be turned to advantage. It is well known that transverse properties are frequently different from axial properties. It would appear that if the specimen were pressed normal to the axis but from many directions and pressed, but differently, also in the axial direction, it might be possible to produce a material that could manifest equivalent physical properties such as fracture toughness both longitudinally and transversely. Further studies are required of the microstructure of this material.

Fluid-to-fluid-extrusion runs were also made on Chrome-30. a billet of Chrome-30 .205" diameter was completely fluid-to-fluid extruded into extremely low back pressure for a reduction in area of 32%. The results of this run were sufficiently encouraging that an additional 20% reduction for a total reduction of 43% was essayed. The result was a small amount of cracking on the nose of the billet, and it is apparent that the use of back pressure will produce sound extrusions of at least 50% reductions in area.

Of major interest, however, was the corroboration of the orthotropic texture of the Chrome-30 material by the appearance of the fluid-to-fluid-extruded specimens. Figure 3 shows the tail of the 43% reduced specimen. Ordinarily the tail of fluid-to-fluid extrusion shows more or less conical cupping, indicative of isotropic deformation. It can be seen that this tail manifests a trough instead of a cup showing that the material flowed more easily on two opposite sides of the specimen than on the sides at right angles. Visual observation of the specimen shows it almost to exhibit "ears".

Even though it was realized that reduction ratios exceeding 43% would require back pressure, one was made into essentially no back pressure with a single reduction of 53%. The results are shown in figure 4. This partial extrusion resulted in cracking transversely along the extrusion. It is interesting to note that the nose of the extrusion also shows the anisotropic behavior that seems to typify Chrome-30.

It has thus been demonstrated that Chrome-30 can be fluid-to-fluid extruded soundly and completely into very

Figure 3: 43% reduction in area by fluid-to-fluid extrusion into very low back pressure of Chrome-30 rod. The orthotropic texture of this material is evident by the trough formed at the tail of the extrusion instead of a conical cup as usual.

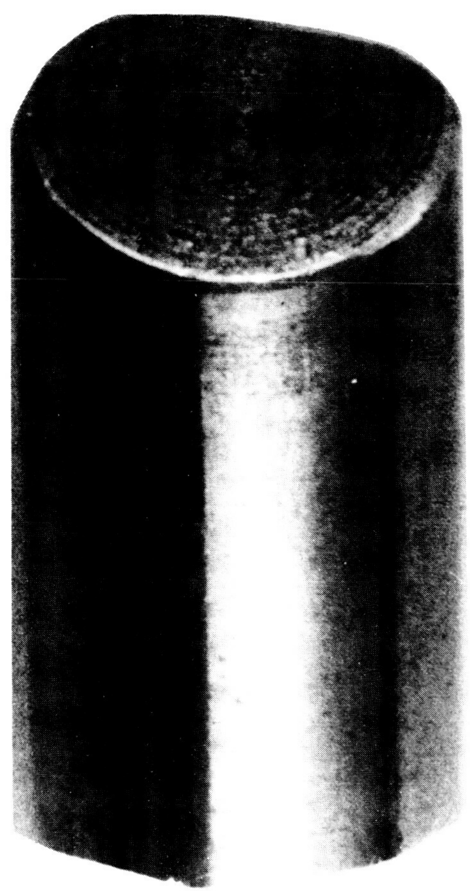
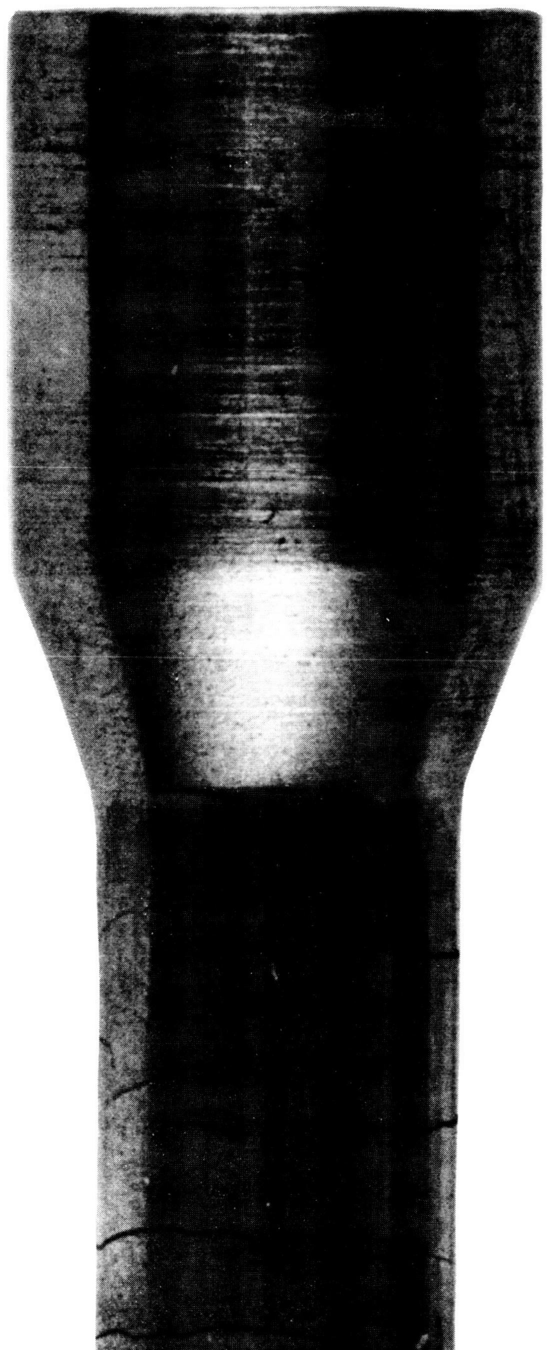


Figure 4: Partial fluid-to-fluid extrusion of Chrome-30 into essentially no back pressure, showing crack of the extrusion and anisotropic deformation in the nose.



low back pressures. The orthotropic texture of the material, however, carries through with the extrusions.

Hafnium Carbide

Several specimens of hafnium carbide were tested in tension under hydrostatic pressure. The material is relatively brittle and some breakage occurred in handling alone. There were, however, three specimens that fractured at environmental fluid pressures of 332,000, 340,000, and 370,000 psi respectively. All fractures were brittle and all were at a sharp shoulder in the gage section. In one test, a yield strength of 50,000 psi was obtained, but the yield strengths were not clear in data from the other two tests.

There is not yet complete satisfaction with these data. Attempts are being made to obtain additional specimen material for further tests, since the supply of specimens is now exhausted.

Tungsten Tantalum alloy

Tensile tests were conducted under pressure on 4.5% tantalum-arc-cast-tungsten ingot. It was previously reported that a specimen had fractured at 311,000 psi, manifested a yield strength of 120,000 psi, UTS 150,000 psi, 4 1/4% elongation and 10% reduction in area. Another specimen was etched completely before test. This etching was done because it was found that cracks had been produced in the ends of the specimens by a cut-off operation, and it was desired to determine whether these cracks extended as far as the test section. Figure 5 shows two views of one such specimen with the cracks clearly apparent after they had been etched. The very large grain size of the cast material can also be seen. Such a grain size results in inhomogeneous deformation. The specimen shown fractured at 421,500 psi with 18% elongation and 59.4% reduction in area. One of the views shows a group of cracks opening up near the final fracture.

In an effort to study this phenomenon further, another test was conducted with an environmental pressure at yield of 282,000 psi (yield strength 130,000 psi). Results of this test are shown in figure 6. This figure shows four views of the specimen. The cracks in the head were due to the cut-off operation and have been etched open. It can be seen that failure is very nearly a process of delamination under the tensile stress. Part of this delamination may be due to unsoundness in the original casting, but it appears that there is a general tendency to behave in this fashion.

Figure 5: Tungsten tantalum alloy tensile test specimen, etched before test, showing cut-off cracks in heads. Specimen fractured at 421,500 psi, with yield strength of 90,000 psi, per-cent elongation 18, and 59.4% reduction in area.

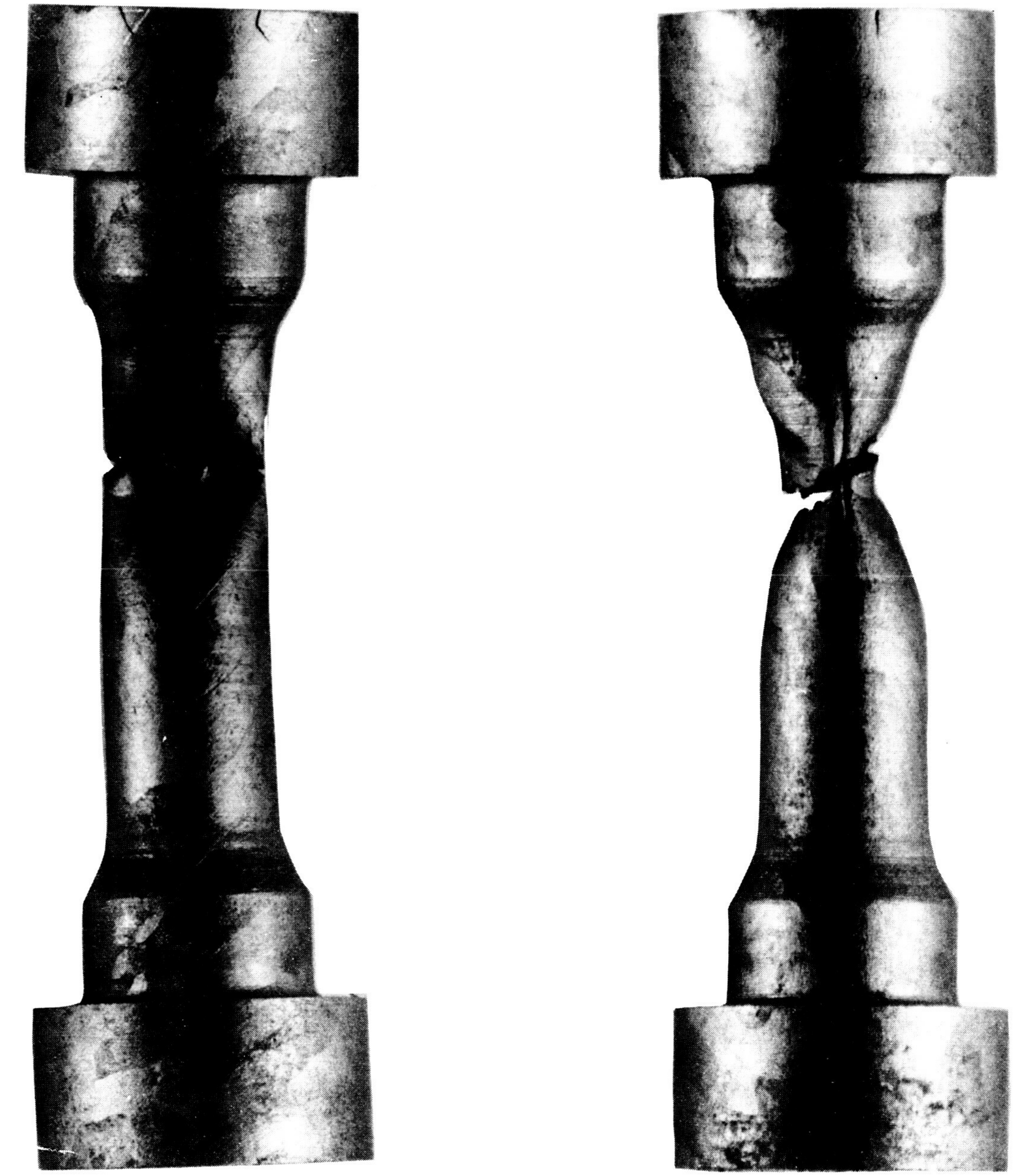
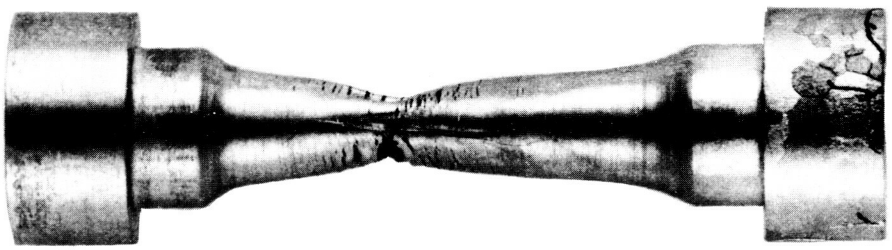
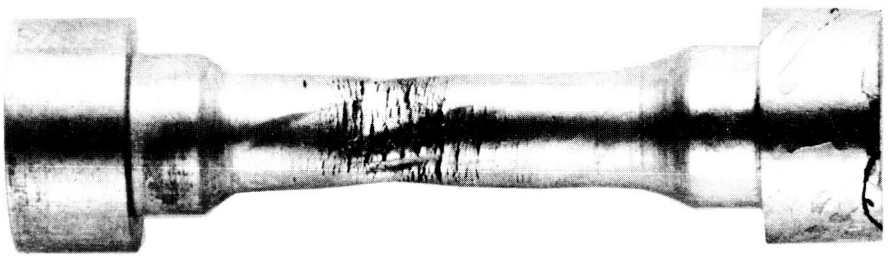
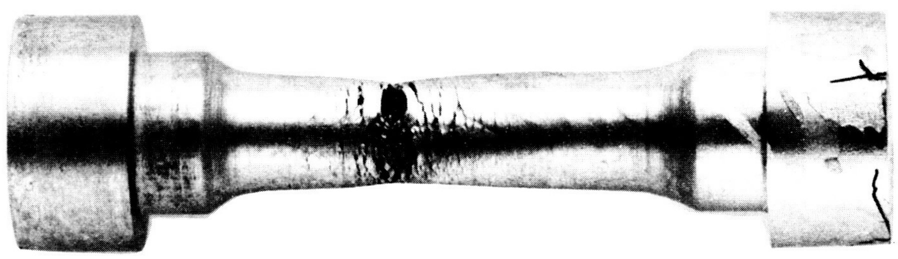
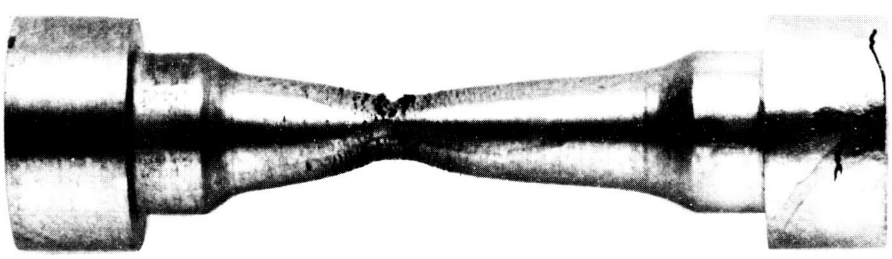


Figure 6: Four views of a tungsten tantalum tensile specimen tested under pressure test stopped short of fracture. Cracks in head have been etched open and do not communicate with the test section.









FUTURE WORK

Future work will be devoted to continuation of the studies reported herein.

REFERENCES

1. BULLEN, F.P.; HENDERSON, F; and WAIN, H.L.: "The effect of Hydrostatic Pressure on Brittleness in Chromium", Phil., Mag., Vol. 9, No. 101, pp 803-815, May 1964.